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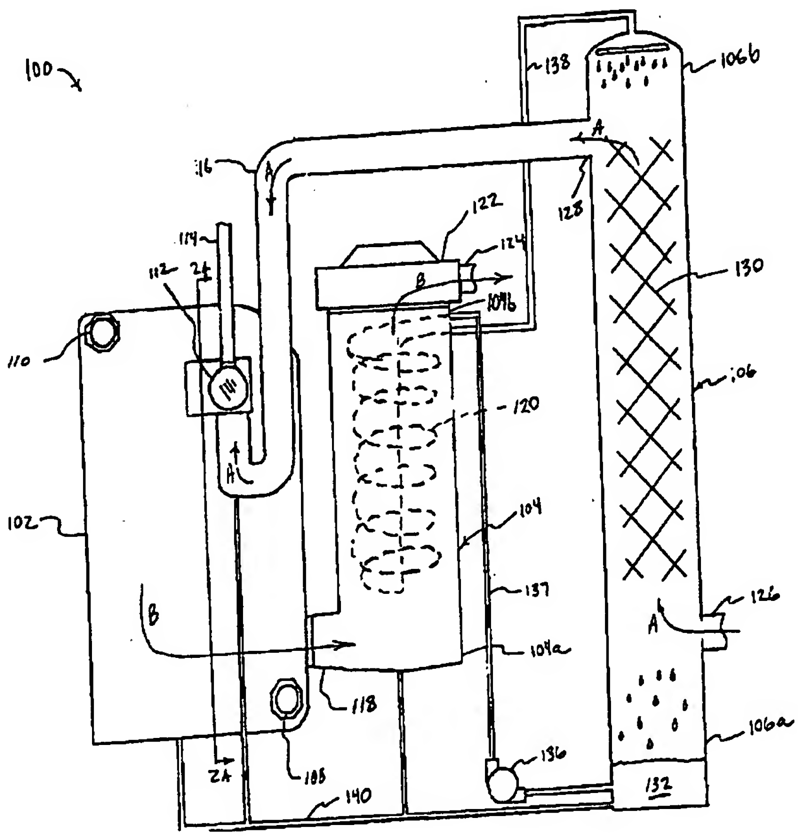
(54) **SYSTEME DE CHAUFFAGE A EAU CHAUDE A HAUT RENDEMENT**

(54) **HIGH EFFICIENCY HYDRONIC HEATING SYSTEM**



(57) Système amélioré et à haut rendement de chauffage des bâtiments qui extrait la chaleur latente et sensible des gaz d'échappement pour réchauffer l'air comburant entrant. Le système comprend un échangeur de chaleur constitué d'un compartiment pour les gaz d'échappement et d'une chambre à eau adjacente. Une

(57) An improved high efficiency space heating system that extracts latent and sensible heat from exhaust gases to warm incoming combustion air. The system includes a heat exchanger having an exhaust gas compartment and an adjacent water chamber. A series of corresponding baffles within the exhaust gas compartment and the

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série de chicanes correspondantes à l'intérieur du compartiment des gaz d'échappement et de la chambre à eau définissent une structure de transfert de chaleur à contre-écoulement transversal. L'échangeur de chaleur est fait de fonte d'aluminium au cours d'un processus qui fait appel à au moins deux noyaux suspendus à l'intérieur d'un moule. Les noyaux forment le compartiment des gaz d'échappement, la chambre à eau et les chicanes placés à l'intérieur. Au moins un noyau comprend une ou plusieurs tiges de soutien et une série de poteaux pour supporter et stabiliser le noyau à l'intérieur du moule au cours de la coulée. Le système comprend en outre un ventilateur assurant un tirage d'air qui se trouve de préférence à l'extrémité de sortie de l'unité de récupération de la chaleur afin de créer une pression négative dans le système. L'unité de récupération de la chaleur sert à récupérer la chaleur latente et sensible des gaz d'échappement. Un appareil régule le fonctionnement du système en fonction des signaux reçus d'un thermostat placé dans l'espace chauffé. L'appareil de régulation comprend une vanne de combustible à deux étapes qui peut être placée dans une position commandant un écoulement élevé du combustible ou un écoulement faible. L'appareil de régulation met d'abord le système en marche, la vanne étant en position d'écoulement élevé du combustible afin d'assurer un allumage fiable. Puis, la vanne est ramenée en position d'écoulement normal du combustible durant la période de fonctionnement.

water chamber define a counter cross-flow heat transfer pattern. The heat exchanger is fabricated from cast aluminum in a process that utilizes at least two cores suspended within a mold. The cores form the exhaust gas compartment and the water chamber and the baffles disposed therein. At least one core includes one or more support rods and a series of posts for supporting and stabilizing the core within the mold during the casting process. The system further includes a draft fan preferably located at the discharge end of a heat recovery unit in order to generate a negative pressure in the system. The heat recovery unit is used to extract the latent and sensible heat from the exhaust gases. A control apparatus governs the operation of the system in response to signals received from a thermostat disposed in the space being heated. The control apparatus includes a two-stage fuel valve which may be moved between a high fuel flow position and a normal fuel flow position. The control apparatus initially starts the system with the valve at the high fuel flow position in order to ensure reliable ignition. Thereafter, the valve is moved to the normal fuel flow position for continued operation.

IMPROVED HIGH-EFFICIENCY HYDRONIC HEATING SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to the field of space heating systems and, more specifically, to an improved heating system that recaptures latent and sensible heat contained in exhaust vapors.

2. Description of the Related Art

Conventional hydronic space heating systems typically use hot water or steam as their primary heating sources. In a forced hot water heating system, for example, hot water is supplied to a plurality of radiators disposed throughout the space being heated. After flowing through and heating the radiators, the cooled water is typically returned to a boiler by a circulating pump, re-heated and again supplied to the radiators. With steam heating systems, steam as opposed to hot water is provided to a plurality of radiators disposed throughout the space being heated. Condensate exiting the radiators is similarly returned to the boiler. In a hydronic forced hot-air heating system, the hot water or steam is typically provided to a heat exchanger. A fan mounted adjacent to the heat exchanger forces cool air past the heat exchanger heating it. The heated air is then supplied to the rooms of the space being heated through an arrangement of ducts extending away from the heat exchanger.

As mentioned above, one or more boilers are often used in these systems to generate the requisite hot water or steam. These boilers typically include a water inlet leading to a hollow interior section for holding the water being heated. A burner extending into or below the lower section of the boiler heats the water, which typically exits the interior section through a passageway at the top of the boiler. Exhaust gases

produced by the burner typically flow upwardly in a sealed channel within the boiler that is separate from the water supply. The exhaust gases, which include combustion by-products (e.g., water vapor, carbon monoxide, carbon dioxide, etc.), are then vented to a chimney and discharged from the building or home being heated. Most boilers are made from cast iron because of its favorable heat transfer characteristics, relative ease of manufacture and long life.

Recently, efforts have been directed to heating systems that extract some of the heat present in the exhaust gases. In conventional heating systems, as described above, the exhaust gases are typically vented from the boiler with a high enough temperature (e.g., 300°F) to ensure that the gases are drawn up the chimney and away from the building or home. U.S. Patent No. 4,989,781 to Eric C. Guyer et al. describes a heating system that transfers the sensible and latent heat present in the exhaust gases to the incoming combustion air. This system is known as a wet recuperative heating system. This heat transfer is accomplished by means of a second heat exchanger that receives exhaust gases exiting the boiler or primary heat exchanger. The secondary heat exchanger may include a length of coiled tubing containing a secondary supply of water. The exhaust gases are forced past the coil, thereby heating the water in the coil. The heated water is then provided to an evaporative water cooler/air heater for use in heating and saturating incoming combustion air. The heated and moisture saturated combustion air is then provided to a burner within the primary heat exchanger improving the overall efficiency of the system. Although the '781 Patent represents a significant advance over the prior art systems, there is nonetheless room for improvement.

First, the process of extracting latent and sensible heat from the exhaust gases results in significant condensation of water and chemical vapors inside the boiler. Such condensation is highly acidic and tends to corrode conventional cast iron boilers. Although the '781 Patent notes that the primary heat exchanger components may be cast or fabricated from material suitable for use in a fired water heater, no further specification is provided. Accordingly, a need has arisen for a boiler formed from a material having improved corrosion resistance over conventional cast iron and a method for fabricating such a boiler or heat exchanger.

In addition, precise control over the flow of water and exhaust gases within the heat exchanger may further improve the transfer of heat. The '781 Patent describes a primary heat exchanger in which combustion products flow past a length of coiled tubing containing water to be heated. Substantial heat transfer takes place through the tubing, yet even greater efficiencies may be achieved by further controlling the flow of exhaust gases and water during the heat transfer process.

Second, in the preferred embodiment, the '781 Patent discloses a system in which a blower is provided proximate to the burner for forcing heated and saturated air to the burner. The blower also provides a positive pressure in the system downstream of the burner, thereby forcing exhaust gases through the boiler, through the secondary heat exchanger and into the flue or chimney. This arrangement has proven quite satisfactory. Nonetheless, positive pressure systems may result in exhaust gases being discharged into the space being heated through leaks in the system. As described above, the exhaust gases include several dangerous components, such as carbon monoxide and carbon dioxide. Therefore, improvements to reduce the likelihood of such leaks are desirable.

Third, prior art boiler control systems do not effectively govern the operation of wet recuperative heating systems such as the system disclosed in the '781 Patent. For example, prior art heating systems typically provide for a single fuel/air ratio during all operating conditions of the boiler, including start-up and continuous operation. Since the fuel/air mixture needed for starting a wet recuperative system may differ substantially from that required for efficient operation, an alternative to the conventional control systems would be advantageous.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an improved boiler or heat exchanger design for use in a wet recuperative heating system.

It is a further object of the present invention to provide a method of fabricating or forming such an improved boiler.

It is a further object of the present invention to reduce the likelihood of exhaust gases escaping into the space being heated.

It is a further object of the present invention to simplify the manufacture, assembly and maintenance of the device used to extract heat from the exhaust gases.

It is a further object of the present invention to provide a control system that ensures proper ignition of the heating system.

It is a further object of the present invention to provide a control system that ensures proper ignition of the system while providing an optimum fuel/air ratio during normal operation.

It is a further object of the present invention to provide a control system that incorporates added safety benefits during operation of the heating system.

The invention relates to an improved high-efficiency heating system including a cast aluminum heat exchanger having improved corrosion resistance as compared to cast iron. The heat exchanger, moreover, employs a counter cross-flow pattern to facilitate the transfer of heat from the exhaust gases to the water supply. More specifically, the heat exchanger includes at least one combustion/exhaust gas compartment adjacent to at least one water chamber. The exhaust gas compartment and water chamber are preferably separated by a dividing wall. The compartment and chamber each include a series of baffles for forcing the corresponding fluid (i.e., exhaust gases or water) to flow in a given pattern opposite to the direction of flow of the adjacent fluid. That is, the flow of water at any given point along the dividing wall is in the opposite direction to the flow of exhaust gases at the corresponding point in the exhaust gas compartment. By forcing the exhaust gases and water to flow in a counter cross-flow pattern, a substantial increase in heat transfer from the exhaust gases to the water can be achieved. Additional heat transfer may be obtained by extending fins from the plane of the dividing wall into the water chamber and/or the exhaust gas compartment.

The invention further relates to a method of fabricating such a heat exchanger via semipermanent mold casting. In accordance with this aspect of the invention, a permanent mold preferably representing one-half of the outer casing of the heat ex-

changer is formed from a suitable material such as steel or cast iron. A serpentine-shaped core is then suspended within the mold in order to form one of the chambers within the heat exchanger and the baffles located within that chamber. Since the serpentine core is relatively fragile, at least one permanent support rod extends transversely through each leg of the core, supporting and stabilizing it within the mold. A series of posts extending from a base of the mold are used to further support the legs of the serpentine core. These posts may lie in a plane substantially orthogonal to the core and support rod. A second core may be suspended above the first to form an adjacent chamber also defining a corresponding serpentine flow path. Molten aluminum is then added to the mold. The aluminum is allowed to harden and the corresponding aluminum cast is removed from the mold. The first core, which is preferably formed from sand, may be broken up and removed from the interior chamber that it defined through a series of openings in the adjacent surface of the heat exchanger. These openings were formed by the posts used to support the core. The openings may then be tapped for insertion of plugs, thereby closing the openings. The support rod or rods preferably remain integral to the heat exchanger. The adjacent core is also removed from the casting. The opposing half of the heat exchanger is similarly fabricated and is the mirror image of the first half. The two halves are then joined together to form a single heat exchanger.

The improved high-efficiency heating system may further include a refined heat recovery unit for extracting latent and sensible heat from the exhaust gases generated in the heat exchanger. The heat recovery unit includes an outer housing with an inlet for receiving exhaust gases from the heat exchanger and an outlet for discharging the exhaust gases. Heat transfer means, such as a coil containing water, are disposed within the housing. The heat recovery unit further includes a draft fan located near the outlet for drawing exhaust gases through the system, including the heat recovery unit, and for forcing those gases through the outlet. By locating a draft fan at the outlet of the heat recovery unit, a negative pressure (relative to ambient air pressure) may be maintained throughout the system. Operation of the system at a negative pressure significantly reduces the likelihood that exhaust gases will be discharged into the space being heated.

That is, with a negative pressure system, leaks would cause outside air to be drawn into the system rather than forcing exhaust gases out of the system. Furthermore, the addition of an orifice plate proximate to the draft fan allows precise control of the amount of negative pressure generated within the system. To further reduce the likelihood of leaks, the heat recovery unit is preferably formed from a single casting.

The system preferably also includes a novel control apparatus providing reliable ignition during start-up, efficient operation during normal operating conditions and automatic shut-down at predefined events. The control apparatus preferably includes control logic having a series of internal timers. A plurality of sensors provide information to the control logic which, in response, operates the heating system. In particular, the control logic is connected to a two-stage fuel valve that regulates the flow or pressure of fuel delivered to the burner. The fuel valve preferably includes a closed position, a high fuel flow position and a normal fuel flow position. A thermostat disposed in the space being heated is also coupled to the control logic so that a signal may be transmitted to the control logic whenever the temperature at the thermostat drops below a preset level. To activate the system, the control logic starts the fan, moves the fuel valve to the high fuel flow position and actuates the burner, among other components. Upon expiration of a timer set at start-up, the control logic preferably moves the valve to the normal fuel flow position for continued operation of the system, having established ignition at the high fuel flow rate. When the temperature at the thermostat reaches a second predefined value, another signal is transmitted to the control logic which, in response, shuts down the system.

For added safety, a vent temperature switch, a casting temperature switch, an inlet pressure switch and an outlet pressure switch are each preferably coupled to the control logic. The vent temperature switch senses the temperature of the exhaust gases exiting the heat recovery unit and transmits a signal to the control logic if the sensed temperature exceeds a maximum level. In response, the control logic preferably deactivates the burner. Similarly, the casting temperature switch transmits a signal if the temperature of the casting exceeds a predefined level, causing the control logic to shut-off the burner. The outlet pressure switch is also located in the exhaust gas stream

preferably at the exit of the heat recovery unit on the suction side of the draft fan. Should the suction pressure fall below a predefined threshold, i.e., increase in absolute pressure terms (indicating a possible blockage in the vent or chimney), a signal is sent to the control logic which, in turn, de-activates the system. The inlet pressure switch is preferably disposed in the combustion air stream proximate to the burner. If the pressure at this switch rises above a pre-set threshold, i.e., decreases in absolute terms (indicating a blockage ahead of the burner), the control logic similarly de-activates the system. Accordingly, the safe operation of the system is further enhanced.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and further advantages of the invention may be better understood by referring to the following description in conjunction with the accompanying drawings, in which:

Fig. 1 is a schematic view of an improved hydronic heating system in accordance with the present invention;

Fig. 2A is a partial cross-sectional end view of the heat exchanger shown in Fig. 1 along lines 2A;

Fig. 2B is a cross-sectional view of the heat exchanger of Fig. 2A along lines 2B, illustrating the exhaust gas compartment;

Fig. 2C is a cross-sectional view of the heat exchanger of Fig. 2A along lines 2C, illustrating the water chamber;

Fig. 3 is a perspective view of a mold for use in fabricating one-half of the heat exchanger of Fig. 1;

Fig. 4 is an exploded perspective view of a heat recovery unit in accordance with the present invention; and

Fig. 5 is a highly schematic block diagram of a control apparatus in accordance with the present invention.

DETAILED DESCRIPTION OF AN ILLUSTRATIVE EMBODIMENT

Fig. 1 is a schematic view of an improved heating system 100 according to the present invention. The heating system 100 includes a heat exchanger 102, a heat recov-

ery unit 104 and an air intake heater 106. The heat exchanger 102 includes a burner 112 that preferably runs on natural gas or propane supplied via a gas line 114. A supply of air is provided to the burner 112 from a combustion air duct 116. A primary water supply enters the heat exchanger 102 at a water inlet 108. As described below, heated water exits the heat exchanger 102 at a water outlet 110 and may be used to heat the corresponding space. That is, the hot water or steam produced by the system 100 may be supplied to forced hot-water, steam or forced hot-air heating components (not shown). As described in more detail below, the heat exchanger 102 is preferably formed from cast aluminum. Suitable aluminum alloys for use in casting heat exchanger 102 include alloy A-356.

The heat recovery unit 104 is used to extract latent and sensible heat remaining in the exhaust gases exiting the heat exchanger 102. The heat recovery unit 104 includes a lower portion 104a, an upper portion 104b and an inlet 118 preferably disposed at the lower portion 104b. The heat recovery unit 104 is coupled to the heat exchanger 102 so that exhaust gases exiting the heat exchanger 102 flow into the heat recovery unit 104 through inlet 118. Disposed within the heat recovery unit 104 are heat transfer means, such as a coil 120, shown in phantom. A secondary water supply that is separate from the primary water supply flows through coil 120. A draft fan 122 is mounted to the heat recovery unit 104 preferably at the upper portion 104b. The fan 122 includes an outlet 124 for discharging the exhaust gases from the system 100 to a vent pipe (not shown).

The intake air heater 106 similarly includes a lower portion 106a and an upper portion 106b and is used to transfer the heat extracted from the exhaust gases to intake air used by the burner 112. An air inlet 126 for accepting ambient air is preferably disposed toward the lower portion 106a and an air outlet 128 coupled to the combustion air duct 116 is disposed toward the upper portion 106b. Disposed within the intake air heater 106 are direct contact heat exchange means, such as packing material 130. A sump 132 containing the secondary water supply is located at the lower portion 106a of intake air heater 106. A pump 136 draws cool water from sump 132, passes it to the

coil 120 via a supply line 137 and delivers it to the upper portion 106b of intake air heater 106 via a secondary water line 138.

Since a continuous flow path from the fan 122 through burner 112 to the intake air heater 106 exists, operation of fan 122 draws ambient air through intake air heater 106 and combustion air duct 116 to burner 112 as shown by arrows A. Burner 112 combines the combustion air with fuel to form a fuel/air mixture which is ignited, thereby generating hot exhaust gases within heat exchanger 102. Heat from the exhaust gases is used to heat primary water entering the heat exchanger 102 at water inlet 108. Heated primary water (or steam) exits the heat exchanger 102 at water outlet 110. Exhaust gases are drawn by fan 122 through the heat exchanger 102 and into the heat recovery unit 104 via inlet 118 as shown by arrows B. Fan 122 also discharges the exhaust gases from the system 100 through the outlet 124. As the exhaust gases are drawn through the heat recovery unit 104, latent and sensible heat are extracted and the secondary water disposed in coil 120 is warmed. Pump 136 via water line 138 forces the warm secondary water from coil 120 to the upper portion 106b of air intake heater 106. Coil 120 is replenished with cool water from sump 132. The warmed water provided to the intake air heater 106 cascades through packing material 130 as intake air flows upwardly, thereby heating and saturating the intake air and cooling the secondary water being collected at sump 132. This heated, saturated air is then provided to burner 112 via combustion air duct 116, as described above. By running a mixture of fuel and heated, saturated air, the operating efficiency of burner 112 is significantly improved. Water droplets collected at burner 112 and condensation collected at heat exchanger 102 and heat recovery unit 104 may be collected by an arrangement of return lines 140 and provided to sump 132.

Figs. 2A-2C illustrate the design of heat exchanger 102. In particular, Fig. 2A is a partial cross-sectional end view of a heat exchanger 202. Figs. 2B and 2C are cross-sectional views of the heat exchanger 202 along parallel but offset planes. The heat exchanger 202 includes at least one exhaust gas compartment 242 (Figs. 2A and 2B) and at least one primary water chamber 244 (Figs. 2A and 2C) separated by a dividing wall 246 (Fig. 2A). The dividing wall 246 seals exhaust gas compartment 242

from the adjacent water chamber 244 so that no intermingling of exhausts gases and primary water can occur. A burner 212 mounted to the heat exchanger 202 extends through water chamber 244 and into exhaust gas compartment 242.

A series of exhaust gas baffles 248 are disposed within the gas compartment 242 of the heat exchanger 202 in order to define a serpentine-shaped gas flow path as shown by arrows A (Fig. 2B). Exhaust gases generated by the burner 212 within chamber 242 travel along the serpentine-shaped flow path and exit the chamber 242 at an exhaust gas outlet 217. The outlet 217 is preferably connected to the inlet 118 (Fig. 1) of the heat recovery unit 104. The water chamber 244 includes a water inlet 208 and a water outlet 210. In addition, a series of water baffles 249 are disposed within the water chamber 244 of the heat exchanger 202. The water baffles 249 similarly define a serpentine-shaped water flow path as shown by arrows B (Fig. 2C). Water entering chamber 244 at inlet 208 flows along the serpentine path by virtue of the water baffles 249.

As shown in Figs. 2B and 2C, the exhaust gas baffles 248 and water baffles 249 are preferably arranged within their respective compartments 242, 244 such that the exhaust gases and water progress through the heat exchanger 202 in a counter cross-flow heat transfer pattern. More specifically, as shown by arrows A and B, the exhaust gases and water flow in opposite directions to each other within heat exchanger 202. Such counter cross-flow patterns substantially improve the rate of heat transfer between the hot exhaust gases and the water flowing through the heat exchanger 202. Furthermore, water baffles 249 (and hence the exhaust gas baffles 248) are preferably disposed along substantially horizontal planes when the heat exchanger 202 is mounted for operation within the heating system 100 (Fig. 1). This tends to avoid possible flow disruptions from buoyancy forces acting on the water as it is heated. Since warm water is less dense than cooler water, buoyancy forces cause warm water to rise relative to cooler water. These forces may cause flow disruptions in vertical flow paths. By arranging water baffles 249 horizontally, such vertical flow paths are minimized. Similarly, water outlet 210 is preferably disposed at a higher elevation than the inlet 208 in order to allow the buoyancy forces to assist in drawing the water through the heat exchanger 202.

To further improve the rate of heat transfer from the hot exhaust gases to the water in water chamber 244, a series of fins 251 (Fig. 2A) may be mounted to the dividing wall 246. The fins 251 preferably extend from wall 246 into the water chamber 244 and are disposed proximate to the burner 212. The fins 251 effectively increase the surface area of the dividing wall 246 on the water chamber side, thereby increasing the rate of heat transfer through the dividing wall 246 and reducing the localized wall temperature. Since the high temperature strength of cast aluminum is typically less than that of cast iron and cast aluminum is susceptible to thermal stress fatigue, the addition of fins 251 likely increases the useful life of cast aluminum heat exchangers operating under normal conditions.

It should be understood that a plurality of short columns (not shown) may similarly extend from the dividing wall into the exhaust gas compartment.

Referring to Fig. 3, a method of fabricating the heat exchanger 202 using the technique of semipermanent mold casting will be described. First, a permanent mold 301 is constructed having an interior surface 301a that coincides with the outer surface of one-half of the heat exchanger 202 (Fig. 2A). The interior surface 301a includes a lower surface 301b. The manner of constructing such a permanent mold is well known to those skilled in the art and thus will not be discussed herein. To form a void or hollow space within a permanent mold, a sand core may be suspended within the mold in the place of the desired void. In conventional cast iron boilers, the sand core is typically rectangular-shaped and is supported within the corresponding mold by four structural elements one located at each corner of the core. To create heat exchanger 202 including water chamber 244 having water baffles 249, a serpentine core 303 is formed in the shape of the desired water flow path. The core 303 preferably includes a plurality of legs 303a and a water outlet form 303b. The spacing between adjacent legs 303a defines the water baffles 249 (Fig. 2C). The outlet form 303b preferably includes a plurality of indentations 303c corresponding to fins 251 (Fig. 2A).

The core 303 may be formed from conventional casting sand, e.g., oil-bonded sand or resin-bonded sand, which is a mixture of sand and binding agents. It should be understood that other materials such as plaster may also be employed.

The serpentine core 303 which has multiple legs 303a and water outlet form 303b is too fragile to be suspended in accordance with conventional casting techniques (e.g., a support at each corner). Accordingly, a novel supporting arrangement has been developed. More specifically, two support rods 352 spaced slightly apart are extended through each leg 303a of the core 303 and into water outlet form 303b. The support rods 352 preferably lie within the plane defined by the serpentine core 303 and extend transversely through each leg 303a. The support rods 352 add stability and support to the serpentine-shaped core 303.

The core 303 is preferably elevated within mold 301 by a series of leg posts 305 and two corner posts 309 projecting upwardly from the lower surface 301b of the mold 301. Each leg post 305, which may also be formed from casting sand, preferably supports a corresponding leg 303a of the core 303. The leg posts 305, moreover, may be aligned between the two support rods 352. The two corner posts 309 (which represent the water inlet and outlet of the resulting heat exchanger) also extend above the core 303. Since each post 305 represents an unnecessary opening in the resulting heat exchanger, as explained below, it is desirable to minimize the number of posts 305 used to cast the heat exchanger. This is achieved, in part, by support rods 352. Due to the stability gained through the support rods 352, only one post 305 is required to support each leg 303a of the core 303. Thus, utilization of the support rods 352 minimizes the number of posts 305 that are otherwise required to support the core 303 above the lower surface 301b of the mold 301.

A second core 307 is also disposed within the mold 301 slightly above the first core 305. The second core 307 may also have a plurality of legs 307a defining a serpentine shape and a burner form 307b . The second core 307 corresponds to the exhaust gas compartment 242 (Fig. 2B) such that the spacing between adjacent legs 307a of second core 307 define the exhaust gas baffles 248. The legs 307a and burner form 307b may rest upon a core plate 307c, providing support and stability to legs 307a. The second core 307 is supported above core 303 by the two corner posts 309 which extend upwardly from core 303. The spacing between the two cores 303, 307, moreover, de-

fines the dividing wall 246 (Fig. 2). The two cores 303, 307 may be spaced approximately 7 mm apart.

It should be understood that the legs of the second core preferably comprise a plurality of closely spaced posts (not shown), rather than solid sections, to form the columns, effectively increasing the surface area of the exhaust gas side of the dividing wall.

With the second core 307 in place, molten aluminum is added to mold 301 until the molten aluminum reaches but does not cover the second core 307. A series of gates and sprues (not shown) may be used to ensure that molten aluminum properly fills the mold 301. The molten aluminum is then allowed to harden and the resulting casting is removed from the mold 301. Since the upper, second core 307 was not covered by molten aluminum, it remains exposed and is thus easily removed from the casting. Sand corresponding to the first core 303 may be broken-up and removed through a plurality of openings 254 (Figs. 2A and 2C) in the casting. The openings 254 were formed in the casting as a result of the leg posts 305 which extended from the lower surface 301b of the mold 301 to the first core 303. Each opening 254 may be tapped so that a plug 256 may be inserted therein, thereby closing or blocking the corresponding opening 254.

As shown in Figs. 2A and 2C, the support rods 252 remain integral with the heat exchanger 202 upon completion of the casting process. The support rods 252, moreover, protrude through the water passageways in water chamber 244. Since support rods 252 have relatively narrow diameters or dimensions, they do not significantly affect the flow of water in water chamber 244. Importantly, the support rods 252 (Fig. 2A) do not extend through the dividing wall 246 and thus do not compromise the integrity of the dividing wall 246.

The finished casting defines one-half of the heat exchanger 202. In the preferred embodiment, a second mold (not shown) is assembled similar to mold 301. The second mold which also includes two spaced-apart cores, moreover, represents a mirror image of mold 301. Molten aluminum is similarly provided to the second mold to cre-

ate a second casting that is the mirror image of the casting formed from mold 301. The two castings are then joined together to form one heat exchanger. The finished heat exchanger of the preferred embodiment thus includes two water chambers sandwiching a single internal exhaust gas compartment. Since the two corner posts 309 (Fig. 3) connected the two cores 303, 307 during the casting process, a pair of channels 208a, 208b (Fig. 2B) are formed between the resulting water chamber 244 (Fig. 2C) and exhaust gas compartment 242 (Fig. 2B) in each casting. To prevent the intermingling of exhaust gases and primary water during operation of the heat exchanger, push nipples (not shown) are preferably press fit within these channels 208a, 208b when the two castings are joined together. The push nipples at channels 208a, 210a interconnect the water chamber 244 in each half of the heat exchanger 202 and extend completely through the intermediate exhaust gas compartment 242, sealing the exhaust gas compartment 242 from the two adjacent water chambers 244.

It should be understood that the heat exchanger 202 may include one or more exhaust gas and/or water chambers. It should be further understood that rather than two support rods, one or three or more support rods may be used to support the serpentine-shaped sand core provided that none of the support rods compromise the integrity of the dividing wall or adversely impact the flow of water within the water chamber. It should be further understood that molten aluminum may be provided to the mold under pressure or a vacuum. It should be further understood that the exterior portion of the heat exchanger may be formed from a sand cast as opposed to a permanent mold.

Fig. 4 shows an exploded view of an improved heat recovery unit 404. The heat recovery unit 404 preferably includes a generally cylindrical outer housing 460 having a lower section 460a and an upper section 460b. The housing 460 is open at the upper section 460b and an inlet 462 is located at the lower section 460a. The inlet 462 preferably attaches to coupling 118 (Fig. 1) and thus connects heat recovery unit 404 with the heat exchanger 102. Heat transfer means, such as coil 420, are preferably disposed within the cylindrical housing 460. The coil 420 includes a water inlet 420a which is mated to an inlet fitting 464 extending through the housing 460 preferably at the upper section 460b. A water outlet 420b of the coil 420 similarly mates to an outlet fitting

468 extending through the housing 460 also at the upper section 460b. The coil 420 may thus be connected to water lines 137, 138 (Fig. 1) of the secondary water supply.

An orifice plate 466 is preferably placed over the opening in the upper section 460b of the housing 460 after installation of the coil 420. The orifice plate 466 includes an aperture 466a of predetermined size. Mounted to the upper section 460b of the housing 460 above the orifice plate 466 is a draft fan 422. The draft fan 422 includes an outlet 424 which is used to discharge exhaust gases flowing through heat recovery unit 404 from inlet 462. The draft fan 422 is preferably mounted to the heat recovery unit 404 opposite the inlet 462 so as to provide a negative pressure in the unit 404 as well as throughout the system 100 (Fig. 1). Since a continuous flow path exists from air intake 126 through burner 112 to unit 104, the fan 422 draws combustion air from the intake air heater 106 to the burner 112 in the heat exchanger 102 and similarly draws exhaust gases from the heat exchanger 102 through the heat recovery unit 404. The amount of negative pressure produced in the system 100 is a function of the specifications of the draft fan 422 and the size of the aperture 466a in the orifice plate, among other things. The addition of the orifice plate 466 allows the amount of vacuum drawn within the system 100 to be precisely controlled. In the preferred embodiment, a vacuum of approximately minus two inches of water is established in the system 100 on the upstream side of the draft fan 422.

As set forth above, the use of a negative pressure reduces the likelihood that exhaust gases will be discharged into the space being heated. Instead, any leaks in the system 100 are more likely to result in outside air being drawn into the system 100. In addition, the housing 460 of unit 404 is preferably formed from a single casting with no joints or seams, thereby further reducing the likelihood of any leaks.

Fig. 5 is a highly schematic illustration of a control system 570 for use in operating the improved heating system 100 (Fig. 1). The control system 570 includes, among other elements, circuitry and programming defining control logic block 572 and timers 574. Control logic 572 is preferably microprocessor-based circuitry. A series of sensors provide information to the control logic 572. First, the control logic 572 receives signals from a thermostat 576 that is disposed within the space being heated by

system 100 (Fig. 1). The thermostat 576 contains an adjustable temperature setting and transmits a first signal to control logic 572 if the temperature in the space being heated falls below the preset level and a second signal if the temperature exceeds the preset level. Control logic 572 may also receive signals, as described below, from an inlet air pressure switch 578 that is located in the incoming air stream preferably in combustion air duct 116 (Fig. 1). An outlet pressure switch 580 located in the exhaust gas flow path in proximity to the suction or upstream side of the draft fan 122 (Fig. 1) also provides signals to control logic 572. A vent temperature switch 582 also located in the exhaust gas stream in proximity to outlet 124 transmits a signal to control logic 572 if the temperature of the exhaust gases exceeds a given threshold. A casting temperature switch 583 preferably located on the heat exchanger 202 (Fig. 2A) proximate to the burner 212 monitors the temperature of the heat exchanger 202. A condensate flow switch 584 located in the secondary water supply preferably near pump 136 (Fig. 1) signals the control logic 572 if the flow of water falls below a preset rate. Finally, a fuel pressure switch 585 may be located in fuel line 114 (Fig. 1) to transmit a signal when the rate of fuel flow (e.g., fuel pressure) to the burner 112 exceeds a given value. The information furnished by these sensors may then be used by control logic 572 in conjunction with timers 574 to operate the system 100 (Fig. 1).

More specifically, control logic 572 is connected to a two-stage fuel valve 586 that is disposed in gas line 114 upstream of fuel pressure switch 585. Control logic 572 is also operably coupled to a burner 512, a draft fan 522 and a pump 536. Conventional controllers typically include a fuel valve moveable from a closed position to a single open position. The single open position typically corresponds to a fuel/air mixture for efficient operation of the burner at normal, ambient conditions. Such a controller is inadequate to run the improved heating system 100 of the present invention. More specifically, at start-up the system 100 contains cold, dense air. Following sustained operation, the system 100 will contain hot exhaust gases that are substantially less dense than the cold, start-up air. Due to these density differences, draft fan 122 will draw a higher flow of cold air through the system 100 than hot exhaust gases for a given fan speed. If a conventional controller were utilized, the increased air flow during start-up

would result in a fuel/air mixture that is too lean to ensure reliable ignition of the burner 112. Accordingly, the control system 570 of the present invention preferably includes a two-stage valve 586 having a first stage corresponding to a high fuel flow rate or pressure and a second stage corresponding to a normal fuel flow rate or pressure.

It should be understood that the valve may be continuously movable between its positions or incrementally stepped between each position.

In operation, control logic 572 preferably activates the draft fan 522 to draw combustion air to the burner 512 and purge the system 100 (Fig. 1). A negative pressure upstream of the fan 522 will cause outlet pressure switch 580 to close, confirming the flow of combustion air. Preferably, after warming up one or more ignitors (not shown) disposed in the burner 512, control logic 572 moves fuel valve 586 from the closed position to the high fuel flow rate position and directs the burner 512 to ignite the corresponding fuel/air mixture. This activity preferably takes place in response to a signal from the thermostat 576 indicating that the temperature in the space being heated has dropped below the preset level. Upon moving the fuel valve 586 to the high fuel flow position, the control logic 572 also commences a first timer from timers 574. Opening of fuel valve 586 at the high fuel flow rate or pressure position causes fuel pressure switch 585 to close, thereby transmitting a signal to control logic 572, which, in response, commences a second timer from timers 574. Upon expiration of the first timer, which follows the ignition of the fuel/air mixture and the establishment of hot exhaust gas flow through the system 100 (Fig. 1), control logic 572 moves the fuel valve 586 from the high flow rate position to the normal position. The first timer may be set at approximately thirty seconds. The second timer causes control logic 572 to determine whether fuel pressure switch 585 has opened confirming movement of the fuel valve 586 to the normal position. If pressure switch 585 is still closed upon expiration of the second timer, control logic 572 preferably shuts off the burner 512 and closes fuel valve 586. The second timer may be set at approximately forty-five seconds. In sum, control logic 572 provides a fixed period of high fuel flow operation followed by continuous operation at normal fuel flow and a safety mechanism to verify transition from the high fuel flow rate or pressure to the normal flow rate.

Upon initial start-up of the system 100 (Fig. 1), control logic 572 also activates the pump 536 in order to circulate the secondary water supply through heat recovery unit 104 and air intake heater 106. Control logic 572 also commences a third timer from timers 574 upon activation of pump 536. Upon expiration of the third timer, which may be set at thirty seconds, control logic 572 preferably determines via flow switch 584 whether water is flowing in the secondary water supply. If switch 584 fails to detect water flow, control logic 572 de-activates pump 536, although the system 100 (Fig. 1) is allowed to continue operating. Without water flowing through the coil 120, however, heat will not be extracted from the exhaust gases by the heat recovery unit 104. Accordingly, the temperature of the exhaust gases will begin to rise. If the exhaust gas temperature exceeds the threshold set by the vent temperature switch 582, a signal is transmitted to control logic 572. In response, control logic 572 preferably shuts-off the system 100. That is, control logic 572 deactivates the burner 512, the draft fan 522 and the pump 536 and closes fuel valve 586. The vent temperature switch 582 preferably signals control logic 572 if the exhaust gas temperature exceeds approximately 145° F.

When the vent temperature switch 582 resets due to the cooling of the vent, control logic 572 may re-start the system 100 (Fig. 1). Secondary water collected at sump 132 during shut-down may now be available for use in extracting heat from the exhaust gases via coil 120. The temperature of the exhaust gases may thus be kept below the threshold set at switch 582.

Additional safety features are provided by pressure switches 578, 580. Inlet pressure switch 578 monitors the flow of combustion air through the air intake 126 (Fig. 1) of air intake heater 106 and the combustion air duct 116. Should a blockage occur somewhere in the intake air heater 106, continued operation of draft fan 522 will result in a high negative pressure in the air intake heater 106 and duct 116. This high negative pressure will cause pressure switch 578 to open and transmit a signal to control logic 572. In response, control logic 572 preferably shuts-off the burner 512, thereby preventing any damage from occurring. This situation may occur, for example, if the water level at sump 132 rises above air inlet 126. The draft fan 522 preferably

continues to run for a limited amount of time (e.g., five minutes) so that if the inlet pressure switch 578 closes, indicating that the blockage has cleared, the burner 512 may be re-started. Outlet pressure switch 580 monitors the discharge of exhaust gases from the system 100. If a blockage occurs in the flue or discharge vent, the pressure upstream of draft fan 122 will fall (i.e., increase in absolute terms), causing switch 580 to open and transmit a signal to control logic 572. In response, the control logic 572 preferably shuts down the burner 512. Again, the draft fan 522 preferably continues to run for a limited period of time prior to de-activation of the system 100 (Fig. 1) in case the blockage clears.

In addition to the inlet and outlet pressure switches 578, 580, the casting temperature switch 583 also monitors the safe operation of the system 100. Since the heat exchanger 202 is preferably formed from cast aluminum, operation of the burner 512 without primary water in the heat exchanger 202 may damage the heat exchanger 202. Such damage may be avoided by use of the casting temperature switch 583. More specifically, if the temperature of the heat exchanger 202 (Fig. 2A) exceeds a predefined level, the casting temperature switch 583 transmits a signal to the control logic 572. In response, the control logic 572 preferably de-activates the burner 512, runs the fan 522 for a period of time to cool the heat exchanger 202 and, thereafter, shuts down the system 100.

The foregoing description has been directed to specific embodiments of this invention. It will be apparent, however, that other variations and modifications may be made to the described embodiments, with the attainment of some or all of their advantages. Therefore, it is the object of the appended claims to cover all such variations and modifications as come within the true spirit and scope of the invention.

What is claimed is:

CLAIMS

1. A heat exchanger for use in a space heating system, the heat exchanger comprising:

an exhaust gas compartment;

a plurality of exhaust gas baffles disposed in the exhaust gas compartment, the exhaust gas baffles defining an exhaust gas flow path;

a water chamber adjacent to the exhaust gas compartment; and

a plurality of water baffles disposed in the water chamber, the water baffles defining a water flow path,

wherein the water and gas flow paths are in heat exchange communication with one another and oppositely directed over a region of adjacency.

2. The heat exchanger of claim 1 wherein the exhaust gas baffles are disposed substantially parallel to each other and spaced slightly apart to define a serpentine-shaped exhaust gas flow path.

3. The heat exchanger of claim 2 wherein the water baffles are disposed substantially parallel to each other and spaced slightly apart to define a serpentine-shaped water flow path.

4. The heat exchanger of claim 3 wherein the exhaust gas baffles and the water baffles lie along substantially horizontal planes when the heat exchanger is mounted for operation in the space heating system.

5. The heat exchanger of claim 4 wherein the region of adjacency is a dividing wall.

6. The heat exchanger of claim 5 wherein a plurality of fins extend from the dividing wall into the at least one water compartment.

7. The heat exchanger of claim 6 wherein the heat exchanger has two water chambers separated by a single exhaust gas compartment.

8. The heat exchanger of claim 7 wherein the heat exchanger further comprises:

a water inlet for supplying water to be heated to the water chamber and

a water outlet for removing heated water from the water chamber.

9. A method of casting an aluminum heat exchanger, the method comprising the steps of:

forming a mold having an interior with a lower surface, the interior of the mold defining an exterior of the heat exchanger;

forming a serpentine-shaped core having a plurality of legs, each leg having a corresponding post extending perpendicular from the core;

inserting at least one support rod through each leg of the core;

placing the core within the mold such that the core is elevated above the lower surface by the legs;

forming a second core;

placing the second core in the mold slightly above the serpentine-shaped core;

adding molten aluminum to the mold;

removing the casting from the mold after the aluminum hardens;

removing the serpentine-shaped core from the casting; and

removing the second core from the casting.

10. The method of claim 9 wherein the serpentine-shaped core further includes at least two opposing corners, each corner having a corner mount extending in the same direction as the posts so that the corner mounts also support the second core when placed within the mold.

11. The method of claim 10 wherein the serpentine-shaped core further includes a water outlet form having a plurality of indentations formed therein.

12. The method of claim 11 wherein two support rods spaced slightly apart are inserted through each leg of the serpentine-shaped core.

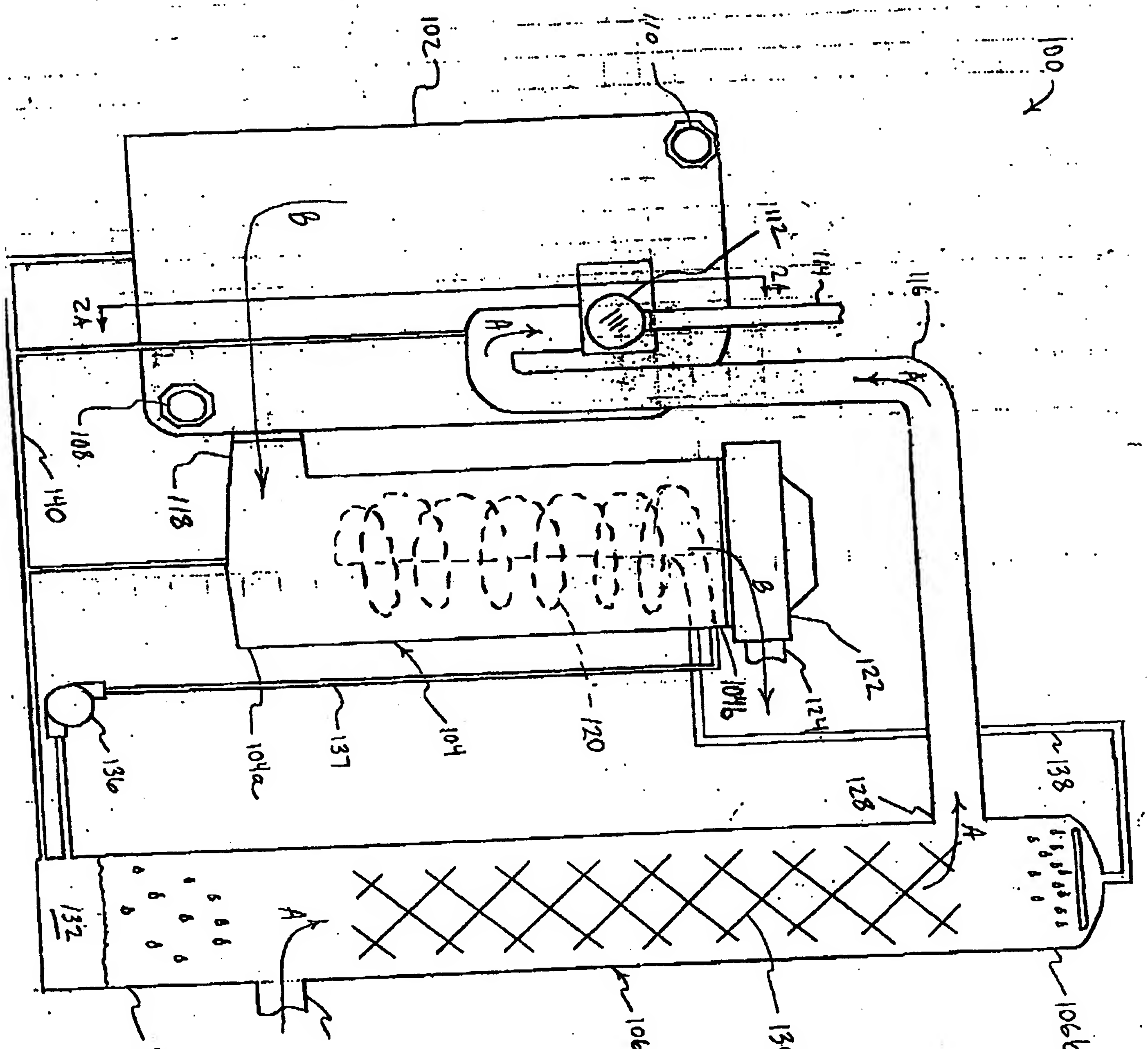
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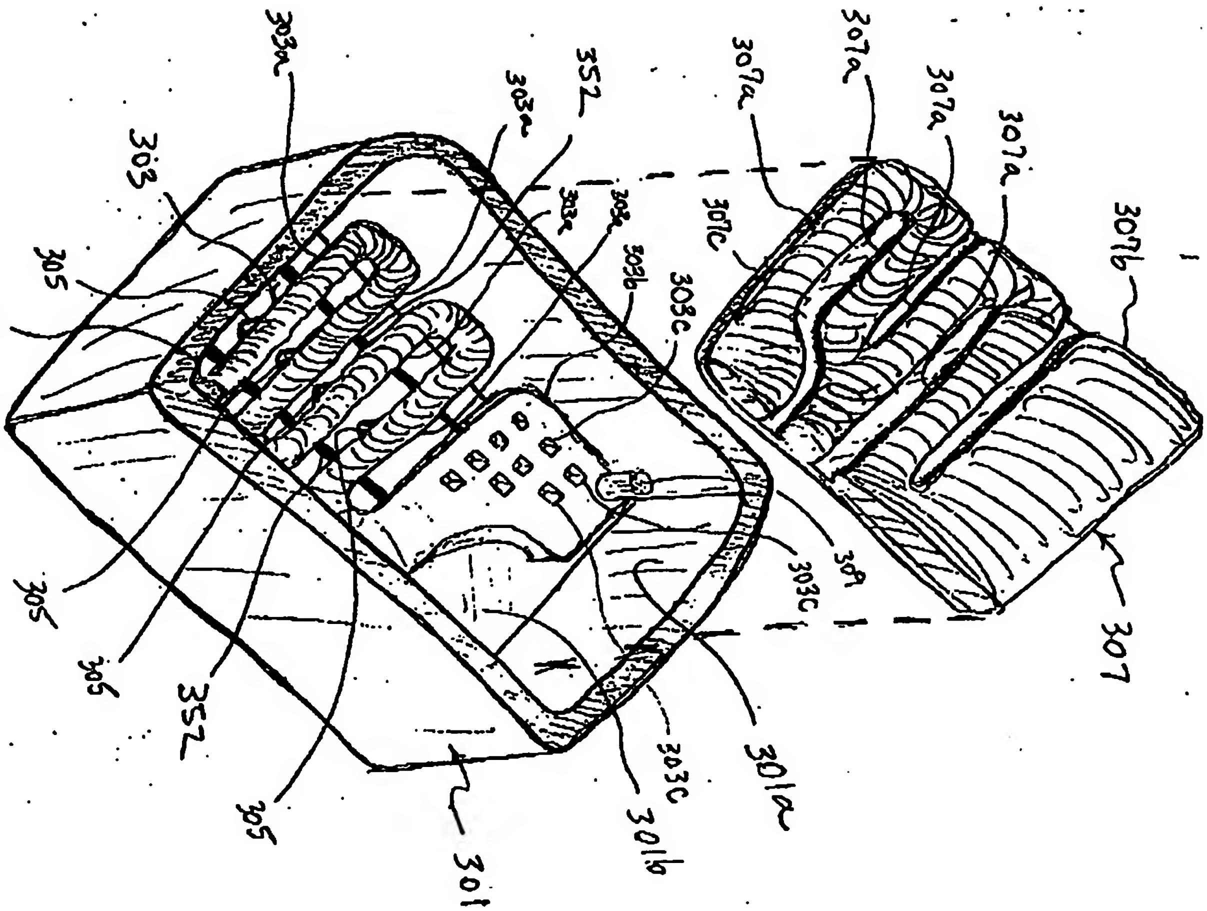
FIG. 1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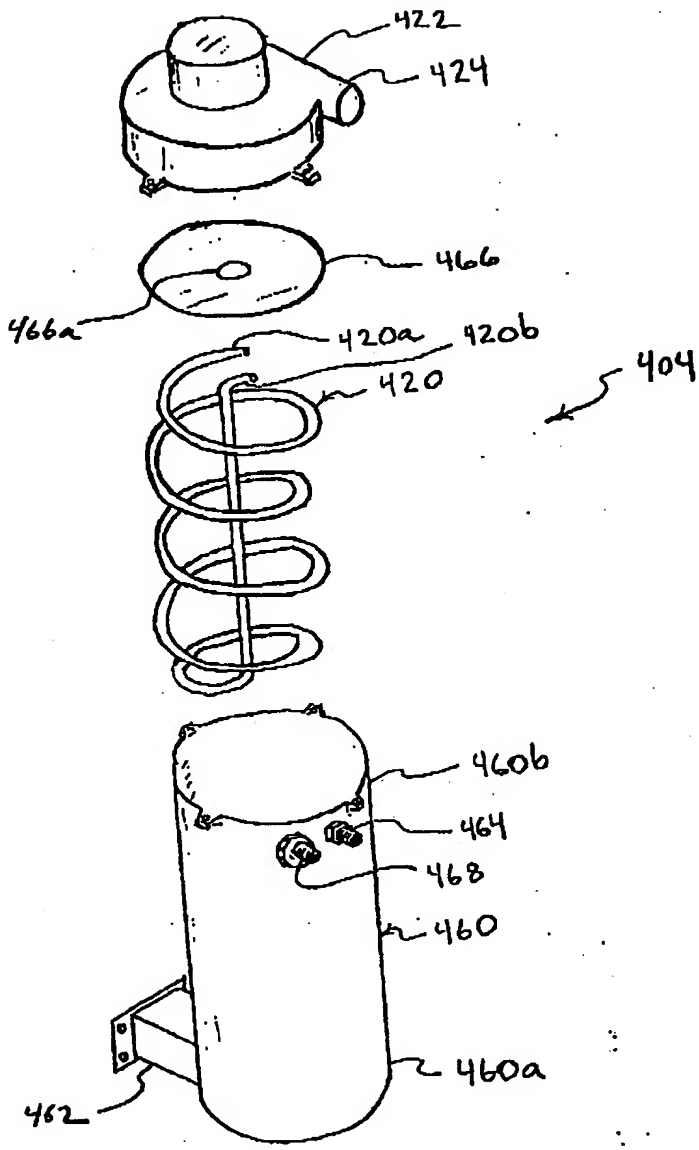
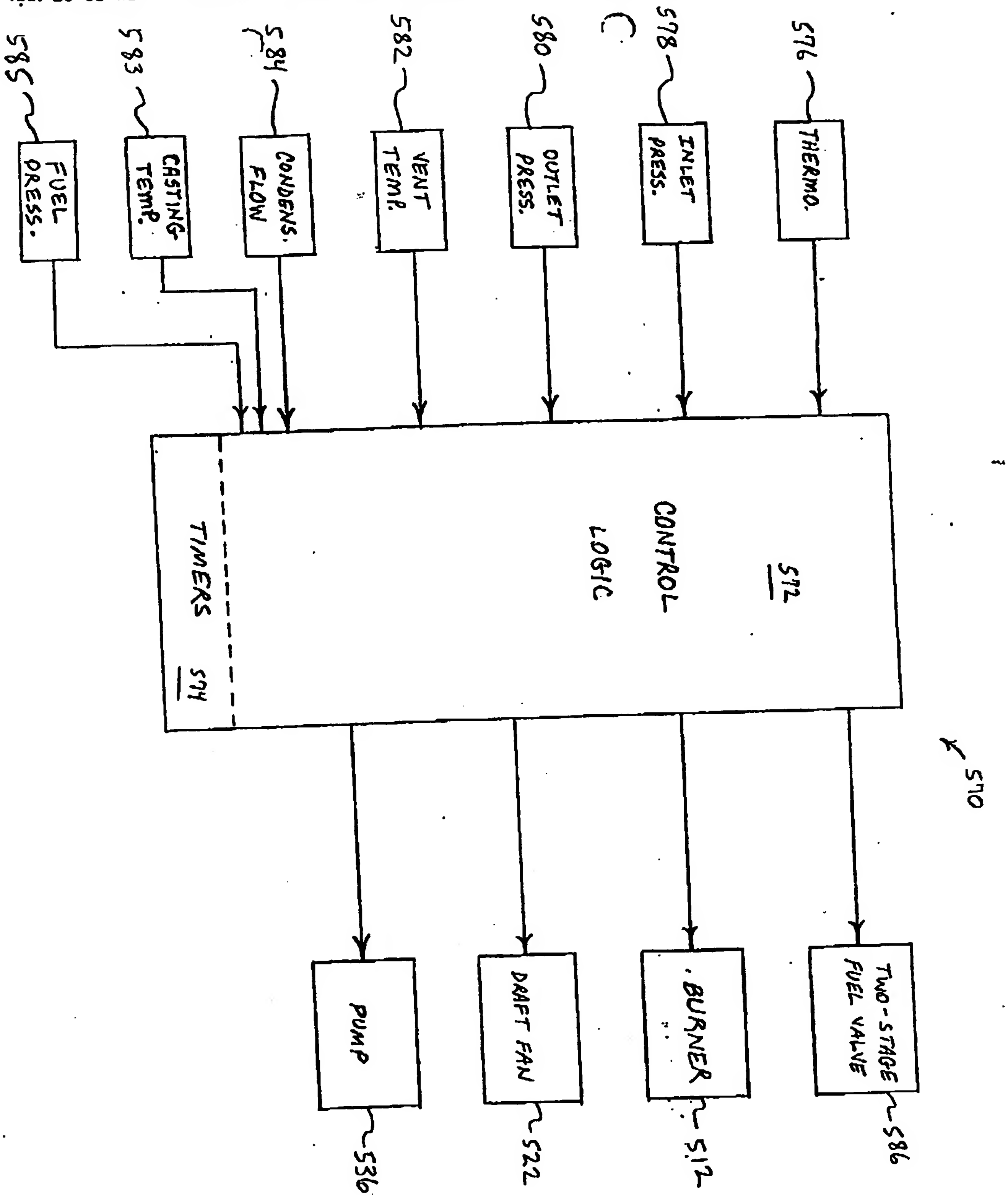


FIG. 4



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FUEL PRESS.
583
CASTING TEMP.
584
CONDENS. FLOW
582
VENT TEMP.
580
OUTLET PRESS.
578
INLET PRESS.
576
THERMO.
TIMERS
574
CONTROL LOGIC
572
570
PUMP
536
DRAFT FAN
522
BURNER
512
TWO-STAGE FUEL VALVE
586

FIG. 5

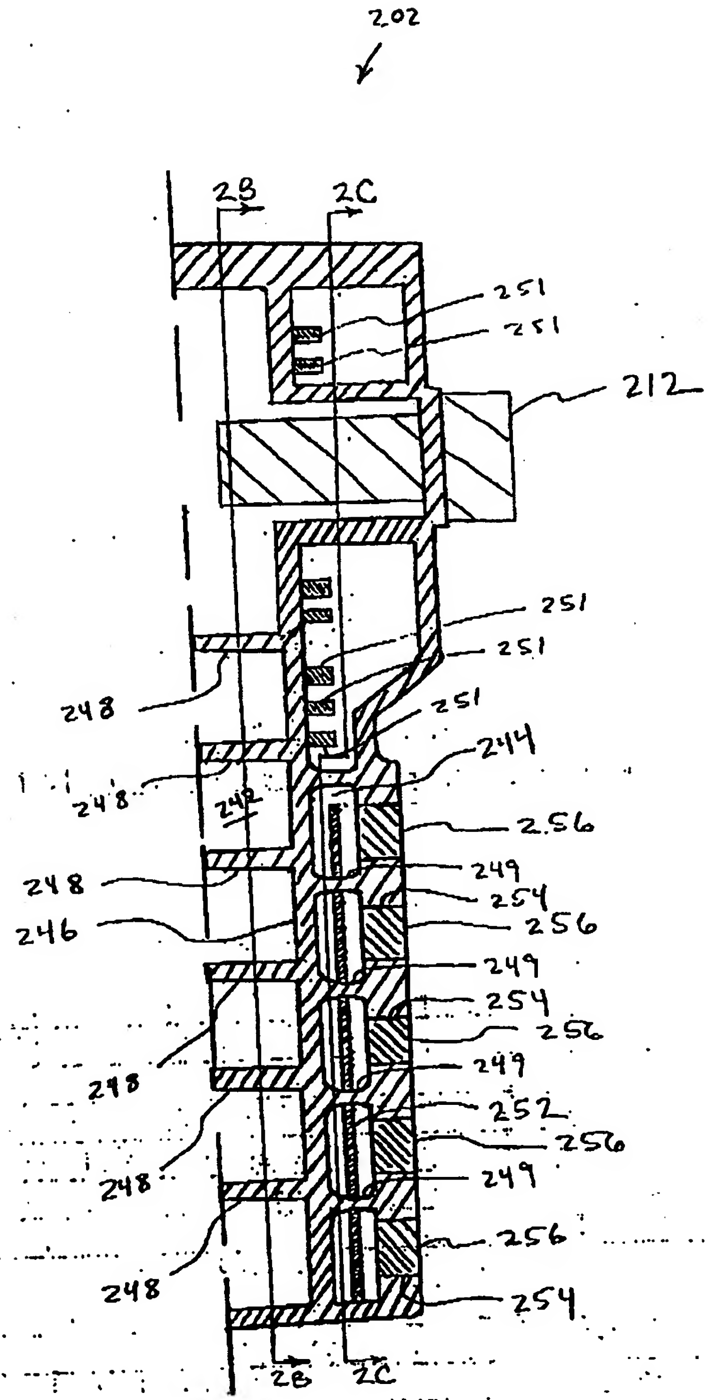
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FIG. 2A

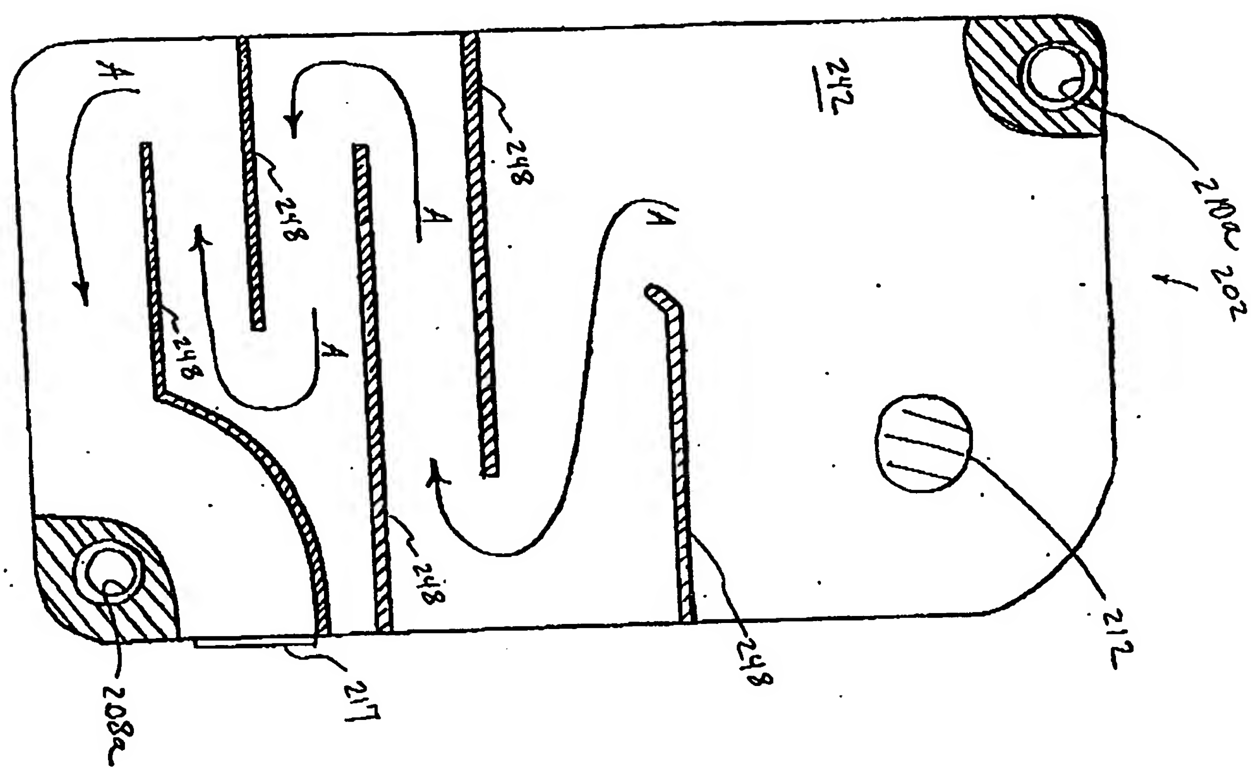

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FIG. 2B

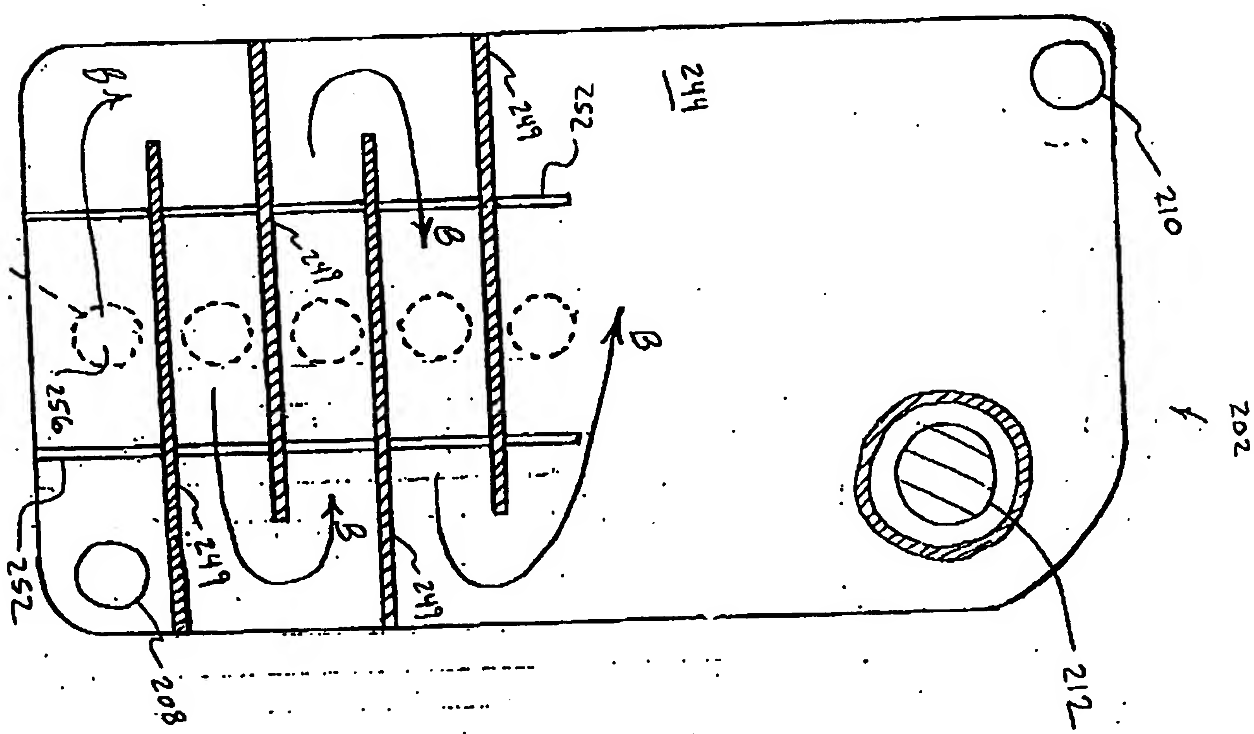

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FIG. 2C